UNDERGROUND COAL GASIFICATION FIELD TEST IN ALBERTA - 1976

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INTRODUCTION

Coal gasification is the processing of a solid fuel - coal - to generate a gaseous fuel. This has been practiced for many years in above-ground gasifiers using mined coal. The process involves primarily the reaction of the carbon in coal with water to generate hydrogen and carbon monoxide. Heat required to make this endothermic reaction proceed is provided by combustion of a portion of the coal. By-products of the reactions are carbon dioxide and pyrolysis products of coal.

In underground coal gasification (UCG) the reactions are carried out in the coal seam. In early applications mined channels were used for communication between the coal seam and the surface and within the coal seam. Technology now is based on channels created from the surface by directional drilling or by linking vertically drilled wells.

In the Canadian context, UCG is viewed as a method of recovering energy from coal resources which for economic or mining reasons lie outside the current limits of mining technology. In particular it should be applicable to very deep coal deposits or to deposits which include substantial amounts of non-combustible mineral matter and are not amenable to conventional mining.

The test described in the present paper dates back to a meeting held in the spring of 1975 at which the Alberta Research Council presented tentative plans for a UCG field test to representatives of interested companies. Response of the companies to the ARC proposal was favourable and over the following months more detailed plans for a field test were drawn up culminating in a meeting held in early February 1976 at which the companies agreed to proceed with the test and to provide part of the funds for it.

Following evaluation of a number of test sites, the Research Council decided upon a site located south of Forestburg, Alberta (about 120 miles southeast of Edmonton - see Figure 1) at the Vesta Mine of Manalta Coal Ltd. A detailed description of the test will be given in the following paragraphs. The test took place during the summer of 1976 with the following objectives:

(a) to better evaluate and understand current technological methods in underground coal gasification;

(b) to demonstrate the feasibility of those technological methods in a Canadian context;

(c) to demonstrate that gas with a low Btu content (a heating value of 100-200 Btu's/SCF) can be produced on a sustained basis; and

(d) to make a preliminary and basic assessment of the factors pertaining to the environment that may be affected by an underground coal gasification test.

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TEST SITE

1. Geological Description

The coal seam in which the test took place is in the Cretaceous, Horseshoe Canyon formation and located in the Battle River coal field. The coal underlies 60 feet of overburden and is immediately overlain by a bentonitic shale. The major fracture direction in the coal is 53° E of N while the minor fracture is at right angles to this at 143° E of N. Water pump tests indicated that the permeability of the coal was sufficiently great that preliminary fracturing would not be required.

Throughout the area of the test site, the coal is present as about 10 feet of coal in a 12 foot seam. There is a hard, continuous shale parting about two feet from the floor of the seam and a soft parting about two feet from the top of the seam. Two water pump tests were carried out to evaluate the directional permeabilities of the coal seam, one in October, 1975, and the other in April, 1976. In planning the test pattern, the major permeability direction used was 53° E of N.

The coal in the seam is subbituminous. Table 1 contains the proximate and ultimate analyses of the coal as well as its calorific value. The water level at the test site (i.e. piezometric height) prior to the test was approximately 8 feet above the top of the coal. Drilling indicated that the water source was located towards the lower portion of the coal seam.

TABLE 1

Coal Analysis *%

	Capacity Moisture Basis	Dry Ash Free Basis
Proximate		
Moisture	21.5	
Ash	23.9	
Volatile Matter	24.5	44.9
Fixed Carbon	30.1	55.1
Ultimate		
Moisture	21.5	
Ash	23.9	
Carbon	40.3	73.8
Hydrogen	2.7	5.0
Sulfur	0.4	0.8
Nitrogen	0.8	1.4
Oxygen	10.4	19.0
Calorific Value (Btu/lb.)	6820	12490

* Composite of samples from vertical water test well through coal seam.

2. Test Plan

The test planned for the Forestburg site was, as the objectives indicate, limited in scope. A rectangular well pattern was drilled to define an area 60 feet by 30 feet, the 60 foot side being in the direction of the major permeability. The test plan involved linking and gasifying the two shorter ends of the pattern in succession, then attempting a 'line drive' of one of the linked sections towards the other. In principle, this should create a long sweeping gasification front which should utilize most of the coal in the given area.

Linking of the wells was to be carried out by reverse combustion which was demonstrated successfully in UCG tests at Hanna, Wyoming. The line drive and gasification of the linked zones were to be carried out in the forward combustion mode.

The effect of UCG on the groundwater was to be monitored by chemical analysis of samples taken prior to, during, and subsequent to the gasification test. Piezometric heights were also to be monitored for possible changes.

To detect movements of the ground at the test site which might be caused by subsidence in the reaction zone, monuments were placed inside and outside the test pattern as shown in Figure 2 and surveyed to provide base data for subsequent surveys during and after the test.

3. Physical Installation

(a) Flow System

The site plan is shown in Figure 2. The air was supplied from the blower and compressor bank or from a portable compressor. Surface piping was provided as shown in Figure 3 so that air could be fed to any well and product gas directed from any other well to the flare stack. The product gas passed through a knock-out drum upstream of the flare stack to remove tars and entrained water.

Gasification wells 1 through 4 were cased and grouted with high temperature grout. Figure 4 shows the method of completing and cementing the wells. Wells 2 and 4 were grouted to the lower part of the seam while wells 1 and 3 were grouted about midway into the coal seam. These wells were cased well into the coal seam to counteract gravity override during linking and gasification.

(b) Instrument System

In addition to the gasification wells, a series of instrumentation wells were drilled within the test pattern. These are shown in Figure 5 as series 1s through 9s and series 1o through 4o.

The 's' series of wells (sampling wells) contained a 1 inch steel pipe for gas sampling and as a support for thermocouples in and above the coal seam as shown in Figure 4. Within the coal seam the sample pipe was perforated. High temperature grout was used to seal and anchor the sampling line within the overburden.

The 'o' series of wells (overburden wells) contained thermocouples located from one to two feet above the top of the coal seam to monitor the penetration of heat into the overburden. These were also to assist in locating the gasification front during the line drive phase of the experiments.

Gas samples were taken from the production wells and gas sampling wells, passed through knock-out pots to remove tar and liquid water and then through lead lines for analysis in a gas chromatograph system located in the control trailer. Sample gas was passed through fibre filters immediately outside the trailer to remove the additional tar and water which condensed during cooling of the gas samples.

Thermocouples were connected to a scanner in the center of the test pattern which in turn was connected to the data logger and computer system for data storage and recording. The complete data collection and processing flow diagram is shown in Figure 6.

Sequencing of the recording of operating data was carried out by a PDP-8M computer having a dual DEC tape system. A teletype copy of the data was generated for the operator and the data stored on magnetic tape for future analysis. Some of the data were plotted by computer to provide a guide for operators during the test.

FIELD TEST OPERATION

Prior to gasification, it is necessary to dry out part of the coal seam and to establish communication within the seam so that air can be circulated. This was carried out in the Forestburg tests by flowing air through the seam between wells 3 and 4 for a number of days. Reverse combustion linking of the 3-4 segment was started August 19th with injection of air and insertion of an electric heater into well 3. The combustion was established in well 3 within three hours and air injection was then switched to carry out the reverse combustion linking stage. The link was completed between wells 3 and 4 by injecting air successively into wells 4s, 5s, 6s and 4. Following completion of the link, forward mode gasification proceeded until carbon dioxide and oxygen levels in the product gas from well 3 indicated that the gasification zone had reached the production well. At this stage the gasification test in the 3-4 zone was terminated and water injected to extinguish the fire prior to commencing operation in the 1-2 zone.

Comparative results from the gasification stage are shown in Figure 7. The volume of gas produced was less than twice the injected air while heating value of the gas produced ranged from 110 to 150 Btu's/SCF. During the gasification of the 3-4 zone, it is estimated that about 160 tons of coal were consumed.

Gasification of the section between wells 1 and 2 was started with ignition in well 1. Following ignition a similar procedure to that followed in the previous link was carried out: that is, the link was made to well 1 successively from wells 1s, 2s and 3s. During the linking stages up to well 3s it was noticed that the linking was more sensitive to variations in the injected pressure and flowrate than it had been in the 3-4 link, and it seemed that relatively small changes in flowrate would cause a change to forward gasification between the injection well and well 1.

When the link had been completed to 3s, it was not possible to get communication to well 2. Perforation of the lower 3 feet of well 2 was carried out to try to alleviate this problem and did in fact increase the air acceptance of well 2. The link was never, however, completed to the stage that sufficient air could be injected to satisfactorily carry out forward gasification of the 1-2 zone.

At this stage it was decided to abandon gasification in the 1-2 zone and to attempt to link directly to the gasified zone between wells 3 and 4. Accordingly, injection was continued into well 2 and also into well 1 with production from wells 3 and 4; that is, a forward combustion link was attempted between zones 1-2 and 3-4. Communication was established quite rapidly with well 3 and there was indication from the thermocouples in well 7s that the reaction had passed by this area. At this stage in the test, however, lateral gas leakage became excessive and product gas was detected in wells beyond the test pattern. In an attempt to limit the loss of product gas to the formation, injection was switched to wells 3 and 4 with production from wells 1 and 2. Product gas continued to be detected outside the limits of the test pattern and the test was terminated.

POST BURN INVESTIGATION

One of the advantages of carrying out the Forestburg test in a shallow coal seam is that the post burn investigations of the gasified zone within the seam can be made more easily and at lower cost. While detailed plans for this post burn investigation are not finalized, several possibilities have been considered and a tentative decision made on the procedure to be followed.

One of the difficulties in evaluating the suitability of a particular coal deposit for underground gasification is the estimation of the utilization of coal within a given area. From previous work it is known that gravity has an influence on the coal utilization as the gasification zone tends to rise towards the top of the seam. For this reason production and injection holes for this test were drilled well into the coal seam. One of the more important and unique investigations in a post burn study of the gasified area would be to measure the degree of utilization of the coal for known conditions of air injection and gas production. Inspection of the boundary of the gasified zone would yield a better appreciation of the mechanism of the gasification process as shown by the separation of combustion and pyrolysis zones. Another factor of interest in post burn studies would be the subsidence of overlying formations into the gasified zone. Information of this kind is not available at present and cannot be deduced from subsidence studies of areas developed by underground coal mining since the overburden in that case, while dried out to some extent, is not subjected to temperatures as high as those encountered during gasification of coal.

Post burn inspection of the gasification area requires mining or excavation of the seam or insertion of remote sensing equipment into the gasified zone. Some of the possibilities are noted below.

The most promising method of post burn evaluation for a shallow site and the method for which detailed plans are now being developed for the Forestburg test site is excavation by strip mining techniques. This entails removal of overburden down to a few feet above the top of the coal seam followed by more careful mining of the gasified zone. Either dragline or scrapers could be used for the initial stripping although the dragline has some advantage if subsidence is anticipated.

Underground mining of the gasified zone has been considered but was ruled out because of safety considerations. Residual highly toxic gas from the gasification process would be an unwarranted hazard to personnel working underground.

Coring through the gasified zone was tried in the earlier Hanna tests. It is difficult, however, to drill into a gasified area without destroying the structure left by the gasification. Coring is useful for indicating the degree of heat penetration into the formations overlying and underlying the gasified zone provided that cores can be recovered.

An initially attractive method would be to suspend a remotely controllable movie camera, television camera or sonar device in the gasified zone. The zone can then be scanned by the remote device through a single borehole. The success of this method is dependent upon the presence of a well defined cavity. This is not likely to exist in this case.

SUMMARY

It is difficult to determine at the moment the differences between the gasification tests in zones 3-4 and 1-2. One obvious difference is that water availability was greater during the initial link and gasification in the 3-4 zone. Subsequent to gasification in the 3-4 zone, water levels throughout the pattern were lowered (up to 12 feet at the gasification wells). This decrease of water availability very likely had a marked influence on the lateral gas leakage noted during linking in the 1-2 zone.

The test did show that fuel gas having a heating value greater than 100 Btu/SCF can be produced from a shallow coal seam and that vertical containment is possible even at depths as shallow as 60 feet. More detailed evaluation of the test must await the analysis of all of the operating data and the results of the groundwater testing and site monitoring programs.

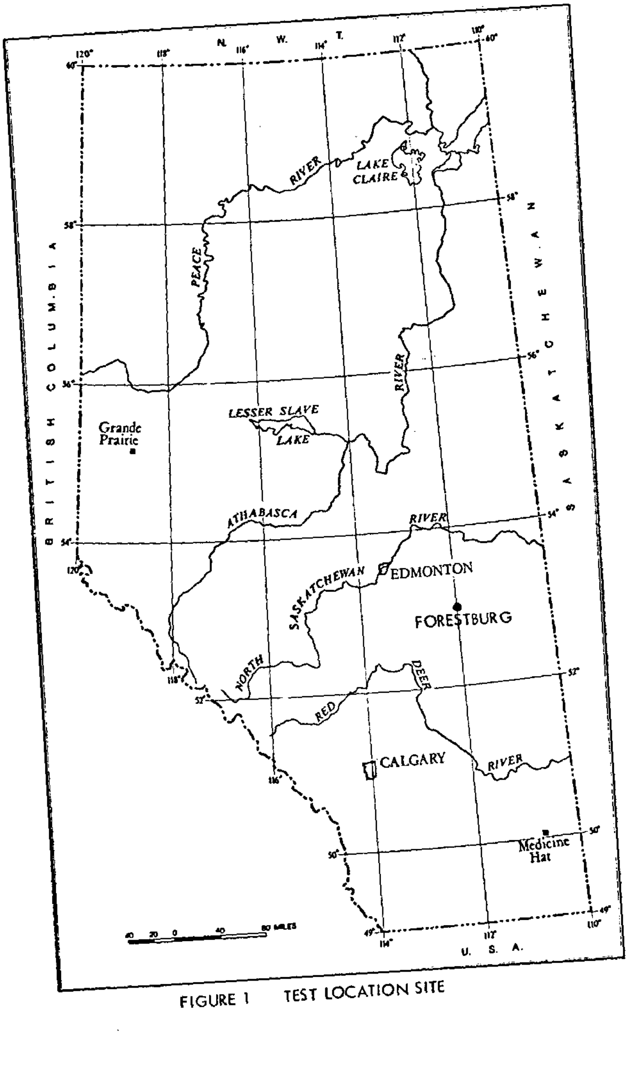

FIGURE 1 TEST LOCATION SITE

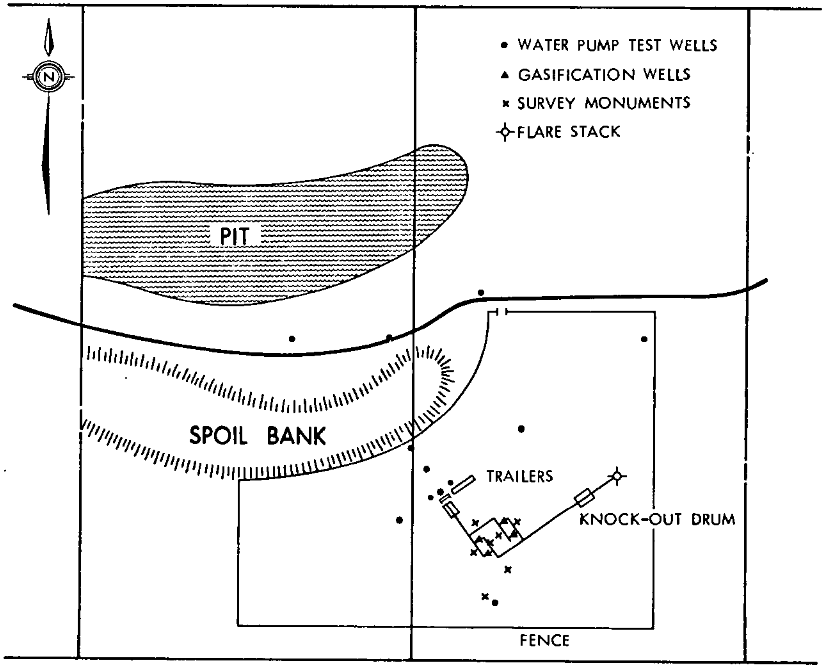

FIGURE 2 SITE PLAN

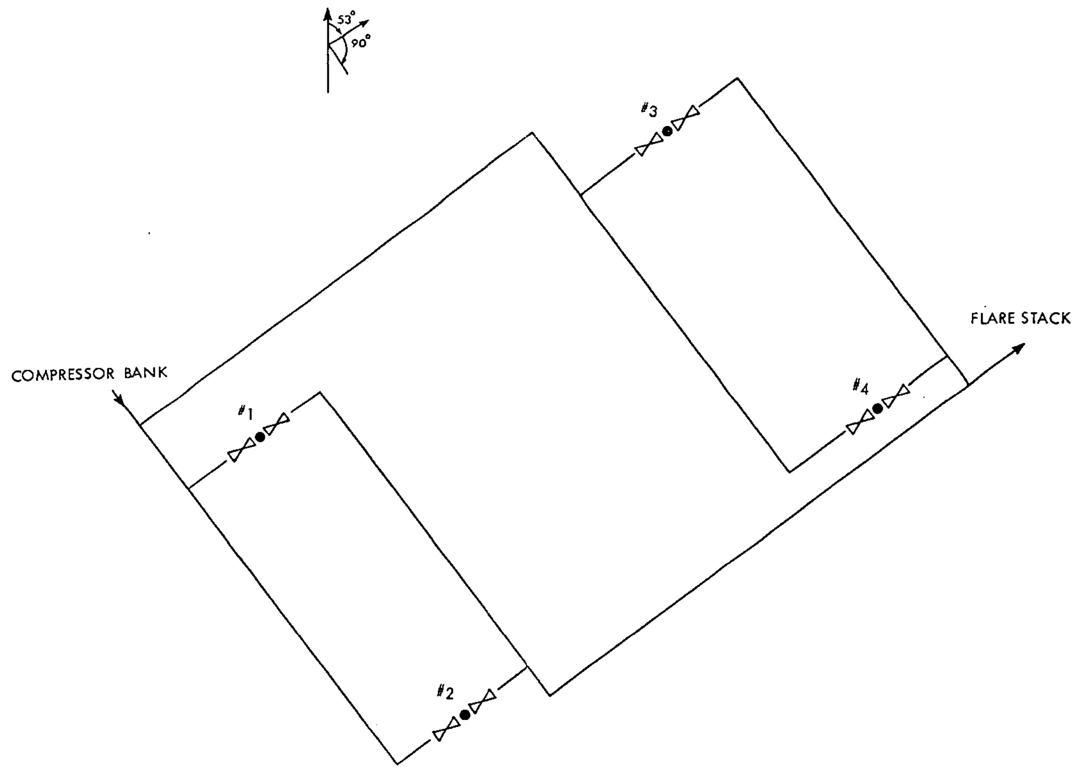

FIGURE 3 SURFACE PIPING PLAN

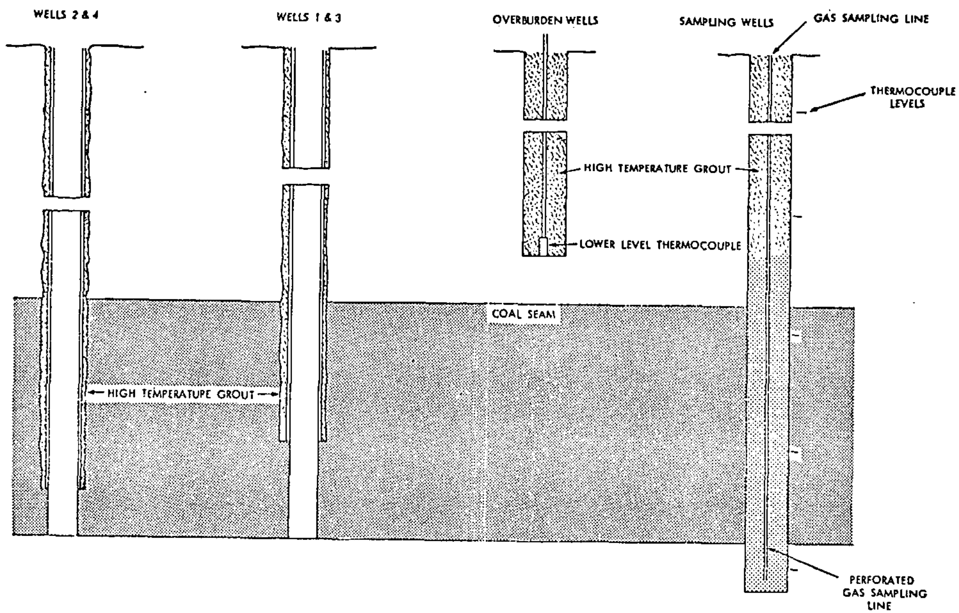

FIGURE 4 TYPES OF WELL COMPLETIONS

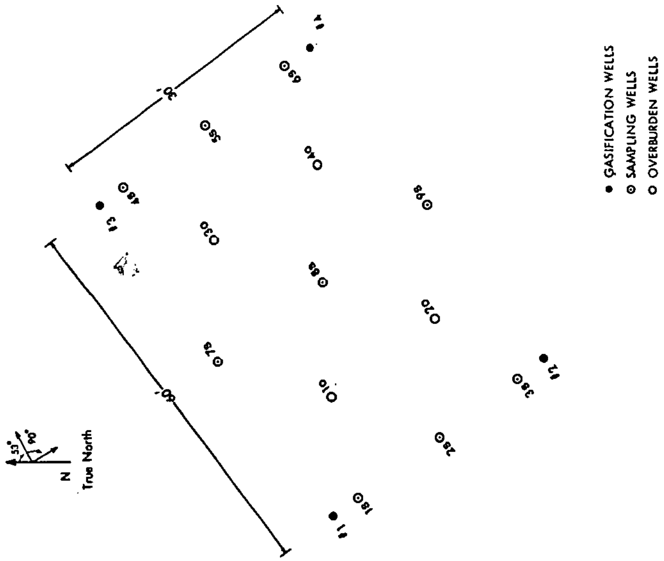

FIGURE 5 INSTRUMENTATION WELL PLAN

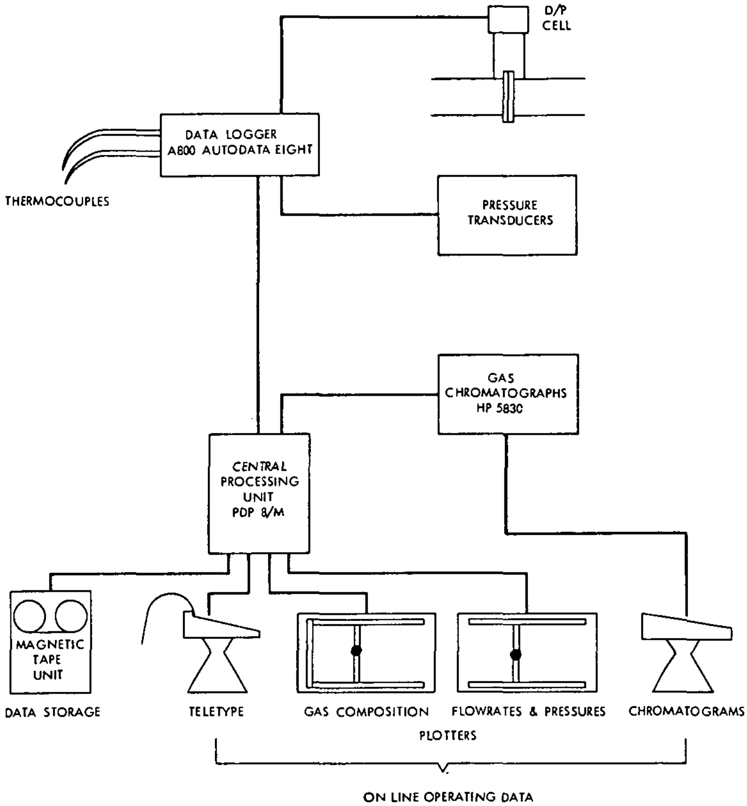

FIGURE 6 DATA PROCESSING NETWORK

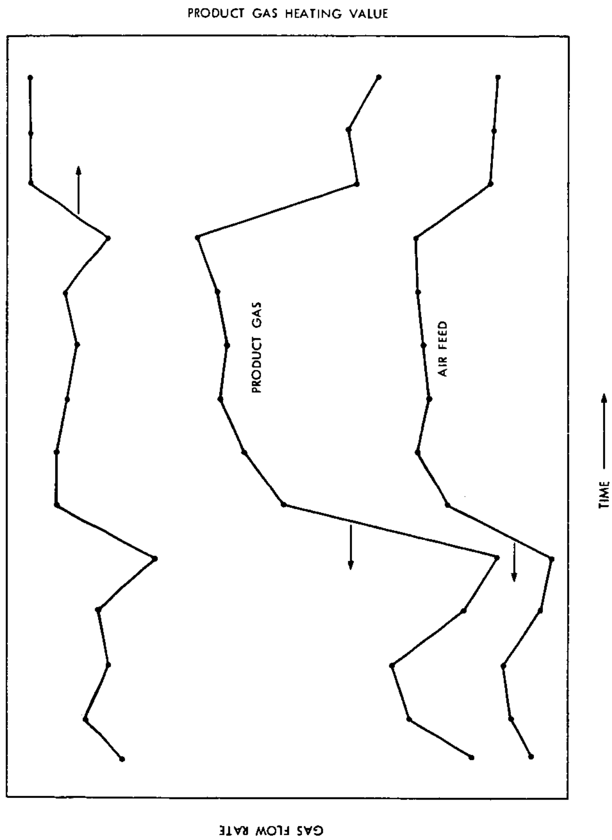

FIGURE 7 PRELIMINARY TEST RESULTS